Docket No. 119-29

COOLING CONTAINER WITH AN ADSORPTION COOLING APPARATUS

This application claims priority from Application No. DE 103 03 292.4, filed on January 28, 2003.

FIELD OF THE INVENTION

The present invention relates to a cooling container with an adsorption cooling apparatus and a method for the operation thereof.

BACKGROUND OF THE INVENTION

Adsorption devices are apparatuses in which a solid sorbent material sorbs a second material, the working fluid, that boils at a lower temperature in the form of steam while liberating heat (sorption phase). In the course of this process, the working fluid evaporates in an evaporator while absorbing heat. After the sorbent material is saturated, it can be desorbed by means of heat input (desorption phase). In the course of this process, the working fluid evaporates from the adsorbing agent. The working fluid steam can be recondensed and can subsequently evaporate again in the evaporator.

Adsorption apparatuses for cooling with solid sorbent materials are known from EP 0 368 111 and from DE-OS 34 25 419. Sorber containers filled with sorbent materials draw off the working fluid steam which develops in an evaporator and sorb it while liberating heat. This heat of sorption must be eliminated from the sorbent materials with which the sorber container is filled. The cooling apparatuses can be used for cooling food and for keeping it warm in thermally insulated boxes.

The sorption cooling system known from EP 0 368 111 comprises a portable cooling unit and a stationary charging station that can be separated from said cooling unit. The cooling unit comprises a sorption container filled with a solid sorbent material and an evaporator which contains a liquid working material and a heat exchanger that is embedded therein. The evaporator and the sorption container are

connected to each other by means of a steam line that can be shut off. Liquid media which are cooled to the temperature level desired by the temperature-controlled opening and shutting off of the shut-off device flow through a heat exchanger that is embedded in the evaporator. Once the sorbent material is saturated with the working fluid, it can be heated in the charging station. The steam draining from the working fluid is recondensed in the evaporator. The heat of condensation is dissipated by cooling water which must flow through the embedded heat exchanger.

The problem to be solved by the present invention is to make available a cooling container with an adsorption cooling apparatus which cools the container content over a relatively long period of time to a low temperature level without an external energy source and the cooling energy of which can be charged at a later time and can subsequently be stored without loss for a random length of time.

SUMMARY OF THE INVENTION

The adsorption cooling apparatus according to the present invention thus comprises a sorbent material inside a sorber container, a valve, and a liquid working material inside the evaporator. During the desorption phase, heat is added to the sorbent material and abstracted during the sorption phase. During the sorption phase, heat of evaporation is added to the working fluid and during the desorption phase, heat of condensation is abstracted. The quantities of heat are transferred to air streams which are transported by means of electrically operated blowers across appropriately designed heated surfaces.

During the desorption phase, working fluid steam is desorbed. This steam flows through the opened or self-opening valve to the evaporator where it condenses out. The transported quantities of air should be large enough to ensure that the heat of condensation can be carried off at a relatively low temperature level. At the end of this phase, the heat input into the sorbent material is stopped. The desorption of additional working fluid steam ends. Closing the valve prevents the working fluid steam from flowing back. The desorbed working fluid is subsequently present in liquid form in the evaporator. In this ready-to-use state, the adsorption cooling apparatus can be stored for a random length of time.

It is useful to line the sorber container with a temperature-stable thermal insulation so as to minimize heat losses to the environment during the desorption process.

To initiate the adsorption phase, the valve is opened. Working fluid steam can now flow from the evaporator into the sorber container and be exothermally sorbed by the sorbent material. Because of the evaporation of a partial quantity, the quantity of working fluid in the evaporator as well as the air stream passing the heat exchanger are cooled. To generate the maximum cooling energy, the sorbent material must be able to dissipate its heat of sorption in a heat exchanger to the environment. An especially intensive cooling effect is obtained when the sorber container has a sufficiently large heat exchanger surface for the air stream that circulates around said sorber container. It is useful if the sorbent material can be cooled to ambient temperatures so as to be able to evaporate the maximum quantity of the working fluid at sufficiently low temperatures of evaporation.

The sorbent material used according to the present invention is zeolite. Per kilogram of zeolite, an adsorption cooling apparatus can store refrigeration energy corresponding to approximately 130 watt-hours without losses and over a random length of time. After the valve is opened, this cooling energy is immediately available. Zeolite is a crystalline mineral which has a regular lattice structure of silicon and aluminum oxides. This lattice structure contains cavities in which water molecules can be sorbed while releasing heat. Within the lattice structure, the water molecules are exposed to strong field forces, the strength of which depends on the quantity of water already contained in the lattice structure and on the temperature of the zeolite. For practical applications, up to 25 grams of water per 100 grams of zeolite can be sorbed. Zeolites are solid materials without interfering heat expansion during the sorption and desorption reaction. The lattice structure is openly accessible on all sides for water vapor molecules. Therefore, adsorption devices can be used in any situation.

It is, however, also possible to use other sorbent material combinations in which the sorbent material is solid and remains solid during the sorption reaction.

Solid sorbent materials, however, are marked by a low thermal conduction and an unsatisfactory heat transfer. Since the heat transfer from an air stream to the sorbent material heat exchanger is also in approximately the same order of magnitude, it is recommended that heat exchangers without ribs, for example, cylindrical, plate or tubular geometries, be used. Since especially zeolite granules have a low thermal conductivity, the sorber containers should be designed to ensure that the average thermal conduction path for the quantities of heat transformed does not exceed 2 cm.

A few solid sorbent materials, such as zeolite, are sufficiently stable to support excessive external pressures without a change in volume even if the container walls are thin. Additional reinforcements or heat exchanger surfaces with thick walls are therefore not needed. Since the sorption device is under a vacuum when water is used as the working fluid and since no gases should enter the system during its operating time, vacuum sealed components should be used. For manual actuation of the valve, lead-throughs that are sealed by means of metal bellows have proven to be useful.

For an efficient operation, zeolite temperatures of 250°C to 350°C for the regeneration phase and 30°C to 50°C for the sorption phase are recommended. It is of special advantage if the regeneration is carried out by means of a hot air stream at air temperatures higher than 300°C. If the zeolite filling is present in a thin layer, the regeneration can be concluded within one hour. Care should be taken to ensure that the condensation temperatures remain under 100°C by ensuring that a sufficient air stream circulates around the evaporator. At higher temperatures, the vapor pressure inside the container would be higher than the air pressure outside, which would necessarily cause container structures with thin walls to be inflated.

The use of water as the working fluid makes it possible to reduce the control mechanism design to a minimum. On evaporation of water under a vacuum, the surface of the water cools down to 0°C and freezes to form ice as the evaporation continues. The layer of ice can be advantageously used to control the air temperature. When only a small quantity of heat is emitted from the air stream, the layer of ice increases, if the quantity of heat emitted is high, the layer of ice melts. If the boiling

temperature of the liquid is to be lowered to below 0°C, it is also possible to mix substances that lower the freezing point to the aqueous working liquid.

The adsorption cooling apparatus is especially suitable for mobile use for which no external energy supply is available. According to the present invention, the energy required to operate the blower is stored in an accumulator. During the desorption phase, this accumulator can be recharged by means of a charging device. To save electrical energy, the blowers are only operated when the cooling temperature desired inside the cooling container has been exceeded. Once the cooling temperature has been reached or falls below the desired cooling temperature, the blower which blows air over the sorber container is also turned off.

The temperatures of the air streams exiting from the evaporator heat exchanger can be controlled by means of known methods via a throttling function of the valve.

According to the present invention, the air temperature can also be controlled independently of the throttle function. For example, to lower the exit temperature of the air stream exiting from the evaporator, the air stream through the sorption heat exchanger can be increased. Since the thermodynamic equilibrium is invariably established when the valve is open, a decrease of the sorbent fluid temperature will entail a decrease of the temperature of evaporation. The air stream exiting from the evaporator therefore necessarily turns colder.

It is also useful to design the valve as a check valve. In this case, the regeneration can even be carried out when the valve is closed. To condense in the evaporator, the working fluid steam flowing off the sorbent material automatically opens the check valve. Since the valve does not need to be opened for the desorption phase, it also does not need to be actively closed at the end of the regeneration phase. This a considerable advantage ensures accurate and simple handling.

A preferred form of the adsorption cooling apparatus according to the present invention, as well as other embodiments, objects, features and advantages of this invention will be apparent from the following detailed description of illustrative

embodiments thereof, which is to be read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

The drawing in Figure 1 shows a diagrammatic sectional view of a cooling container with an adsorption cooling apparatus according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

On the ceiling of the inside of a traveling insulated cooling container 1, an evaporator 2 is located, which evaporator is connected to a sorber container 5 via a working fluid steam line 3 and a check valve 4. Both sorber container 5 and evaporator 2 are plate like heat exchanger configurations. The sorber heat exchanger comprises three plates 6 which contain the sorbent material zeolite 7. The zeolite filling is introduced in the form of prefabricated molded plates into which the distribution structure required for the flow of the working fluid steam is incorporated. Between plates 6, two electrical heating elements 8 are located, via which the air gap between plates 6 and thus plates 6 as such can be heated. Sorber container 5 is enclosed in a thermally insulated flow cabinet 9 through which a sorber blower 10 transports ambient air after the desorption phase and, at times, during the sorption phase. Sorber blower 10 as well as an evaporator blower 12 are fed by an accumulator 11 during the sorption phase. During the sorption phase, evaporator blower 12 circulates the air to be cooled inside cooling container 1 along the paths marked by arrows over evaporator 2 which is screened against the internal chamber by means of an air baffle plate 14. A temperature sensor 15 controls the temperature of the internal chamber. Evaporator 2 is constructed of two flat profile plates 13 in the inside chamber of which supporting elements and a non-woven fabric that distributes the working fluid, water, ensure that the profile plates 13 do not implode and that the working fluid can evaporate evenly. A safety device 17 signals to a control (not shown) whether door 18 is open or closed.

The operation of the cooling container can be divided into a desorption phase and a sorption phase.

During the desorption phase, the two electrical heating elements 8 are operating. As the zeolite temperatures increase, more and more water vapor evaporates from zeolite 7. The increasing vapor pressure opens check valve 4, and the working fluid steam enters evaporator 2 where it condenses. The heat of condensation is dissipated to the air stream which is transported by evaporator blower 12 over profile plates 13. To ensure that the temperature inside the cooling container does not increase too much, door 18 of the container must be open during the desorption phase. This is controlled by safety device 17. If the door is closed and temperature sensor 15 senses that the temperature in the container has exceeded an upper threshold value, electrical heating elements 8 are safety-disconnected or turned off. During the desorption phase, cooling container 1 is connected to the stationary power supply via which electrical heating elements 8 are supplied. At the same time, accumulator 11 is charged. At the end of the desorption phase, heating of the zeolite filling is stopped and sorber blower 10 is turned on. As a result, sorber container 5 cools down to ambient temperature. But steam from evaporator 2 cannot flow back through the automatically closed check valve 4.

Only in the sorption phase can this steam flow back when valve 4 is opened by valve actuating element 16. Now evaporator 2 cools down since the working fluid, water, evaporates. The steam flows into sorber container 5 where it is sorbed by zeolite 7 while releasing heat. This heat of sorption is dissipated into the ambient air by sorber blower 10. Since during the sorption phase, cooling container 1 is generally not connected to the electrical power system, both sorber blower 10 and evaporator blower 12 are operated via accumulator 11. To save electrical energy, both sorber blower 10 and evaporator blower 12 are stopped as soon as temperature sensor 15 senses that the internal temperature in the cooling container has fallen below the preset temperature in the cooling chamber. Thus, it is ensured that especially at the beginning of the cooling phase during which cooling container 5 often must also be preliminarily cooled, the maximum cooling energy is available. Check valve 4 can remain open until cooling container 1 is again connected to the electrical power supply so that it can be recharged.

Although the illustrative embodiments of the present invention have been described herein with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various other changes and modifications may be effected therein by one skilled in the art without departing from the scope or spirit of the invention.